Anagrus spp. (Hymenoptera: Mymaridae) reared from plants collected during winter in south central Washington and north central Oregon

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ABSTRACT

Anagrus daanei S. Triapitsyn, *A. erythroneurae* S. Trjapitzin and Chiappini, and *A. tretiakovae* S. Triapitsyn parasitize western grape leafhopper, *Erythroneura elegantula* Osborn, and Virginia creeper leafhopper, *E. ziczac* Walsh, eggs during the summer. These leafhoppers overwinter as adults and *Anagrus* overwinter in leafhopper eggs. Thus, *Anagrus* must find other leafhopper eggs in which to overwinter. To identify plants on which these parasitoids and their host eggs overwinter, we collected 31 species of plants from 52 sites in the grape growing region of south central Washington and north central Oregon during the winter from 2000 to 2007. A total of 733 female and 1066 male *Anagrus* was reared from the plants. Twelve plant species harboured *Anagrus* spp. during the winter. *Anagrus erythroneurae* was reared from blackberry, *Rubus armeniacus* Focke; willow, *Salix* spp.; Wood's rose, *Rosa woodsii* Lindley; sweetbrier rose, *R. eglanteria* L.; rugose rose, *R. rugosa* Thunberg; and ornamental roses, *Rosa* spp. L. *Anagrus tretiakovae* was found on choke cherry, *Prunus virginiana* L.; rugose rose; *Rosa* spp.; and blackberry. Only one specimen, from ornamental rose, was tentatively identified as *A. daanei*. Other specimens were identified as *A. atomus* L., *A. avalae* Soyka, *A. nr. sp. avalae*, *A. nr. sp. columbi* Perkins, *A. nigriventris* Girault, and *A. nr. sp. nigriventris*.

Key Words: *Anagrus*, *Erythroneura elegantula*, *Erythroneura ziczac*, Mymaridae, *Vitis vinifera*, grape, leafhopper, overwintering

INTRODUCTION

Mymarid wasps in the genus *Anagrus* Haliday (Hymenoptera: Myrmaridae) are egg parasitoids, principally of Homoptera and Heteroptera (Chiappini *et al.* 1996). An *Anagrus* species identified as *A. epos* Girault was determined to be an important biological control agent of the western grape leafhopper, *Erythroneura elegantula* Osborn, in California (Doutt and Nakata 1965) and Washington State (Wells and Cone 1989), and of the Virginia creeper leafhopper, *E. ziczac* Walsh, in British Columbia, Canada (McKenzie and Beirne 1972). However, Trjapitzin (1995) found that the California leafhoppers were not *A. epos* and later identified them as *A. erythroneurae* S. Trjapitzin and Chiappini and *A. daanei* S. Triapitsyn (Triapitsyn 1998). Regardless of the species involved, the main obstacle to successful biological control is that grape leafhoppers overwinter as adults but *Anagrus* wasps need leafhopper eggs in which to overwinter (Doutt and Nakata 1965). Therefore, *Anagrus* spp. must overwinter in the eggs of other leafhopper species on other plants and subsequently recolonize vineyards the following year. In California, *A. epos* [most likely *A. erythroneurae* (Triapitsin 1998)] overwinters on blackberries, *Rubus* L. spp., in the eggs of the leafhopper *Dikrella cruentata* (Gillette) (Doutt and Nakata 1965) and on French prunes in prune leafhopper, *Edwardsiana prunicola* (Edwards), eggs (Kido

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et al. 1984, Wilson *et al.* 1989). McKenzie and Beirne (1972) found *Anagrus* spp. overwintering on wild rose and apple, *Malus domestica* Borkhausen, in British Columbia. In New York, *Anagrus* spp. were reared from 13 plant species collected from December to April (Williams and Martinson 2000). The closer vineyards were to overwintering sites, the better the recolonization by *Anagrus* spp. in the spring (McKenzie and Beirne 1972, Doutt and Nakata 1973, Kido *et al.* 1984, Wilson *et al.* 1989, Corbett and Rosenheim 1996, Murphy *et al.* 1996).

Erythroneura elegantula and *E. ziczac* are leafhopper pests of Washington wine grapes, *Vitis vinifera* L., (Wells and Cone 1989). *Erythroneura elegantula* eggs were parasitized primarily by *A. tretiakovae* S. Triapitsyn but also by *A. erythroneurae*, and *A. daanei*. Most *E. ziczac* eggs were attacked by *A. daanei* but *A. tretiakovae* was also recorded (Prischmann *et al.* 2007). These three species are also the principal *Anagrus* spp. that parasitized grape leafhoppers in New York (Williams and Martinson 2000). The non-grape host plants of two of these *Anagrus* spp. in New York were: black willow, *Salix nigra* L. (*A. erythroneurae)*; sugar maple, *Acer saccharum* Marsh.; black locust, *Robinia pseudoacacia* L.; multiflora rose, *Rosa multiflora* Thunberg; and common prickly ash, *Zanthoxylum americanum* Miller (*A. daanei*). Williams and Martinson (2000) did not report any non-grape hosts for *A. tretiakovae.*

The ultimate objective of the *Anagrus* spp. work is to achieve effective biological control of grape leafhoppers in Washington state vineyards. This will likely involve manipulating the agroecosystem by planting cover crops in or near vineyards (English-Loeb *et al.* 2003) or *Anagrus* spp. overwintering plants near vineyards (Kido *et al.* 1984, Wilson *et al.* 1989, Corbett and Rosenheim 1996, Murphy *et al.* 1996, 1998). One of the first steps toward this objective is to identify the overwintering hosts of *Anagrus* spp. (Prischmann *et al.* 2007). Therefore, the goal of this study was to identify plants that harbour overwintering *Anagrus* spp. that parasitize grape leafhoppers in central Washington.

MATERIALS AND METHODS

Plants were collected from 48 sites in the Yakima Valley of Washington (the principal grape growing area) from near Benton City (46°16'N, 119°29'W), Benton County, in the east to near Harrah (46°24'N, 120°33'W), Yakima County, in the west. The distance between these two sites is about 82 km. Most of these plants were collected near Prosser (46°12'N, 119°46'W). Other Washington sites included two from near Bickleton (46°0'N, 120°18'W), Klickitat County, and one from Little Rattlesnake Cr. valley near Nile (46°49'N, 120°56'W), about 35 km NW of Yakima, Yakima County. One collection from Oregon was from a site near the Umatilla River about one km south of the city of Umatilla (45°55'N, 119°20'W), Umatilla County. The number of samples collected each year from 2000 to 2007 in order were: 11, 35, 20, 18, 19, 11, 9, and 9. Some sites were sampled more than once in different years. Between early January and mid April, branch terminals from the selected plants were cut, placed in plastic bags, and taken to the laboratory. Plants less than about two m in height were sampled by selecting branches from different heights and, if possible, from sun and shaded areas. Branches from taller plants were collected from about two m high or less. Plants were identified using keys and descriptions (Hayes and Garrison 1960, Gilkey and Dennis 1973, Hitchcock and Cronquist 1973, USDA 2007, UWBM 2007). Most of the plants were growing in uncultivated areas. Ornamental roses were sampled near residences. *Rosa rugosa* Thunberg plants were purchased and planted in a vineyard on Washington State University property, about eight km north of Prosser. Plants not identifiable during the winter were revisited

when flowers or leaves were present. Branches from each plant sample were trimmed to about 45 cm in length, the cut ends were inserted into a plastic bucket with water, and placed in an emergence cage (33 w x 46 l x 36 d cm) (Southwood 1978), which was made of plywood or cardboard with a 15 ml glass vial or 237 ml glass jar attached for collecting the emerging *Anagrus* adults. The parasitoids were attracted to the light coming through the collection vials and trapped there. The plant samples were placed in the cages within one day of collection and left in the cages for at least four weeks. The cages were placed in a greenhouse with natural and supplemental lighting (16:8 h L:D). The temperature ranged from about 22 to 28 °C. *Anagrus* spp. specimens were stored in 70% ethanol until they were mounted on microscope slides in Hoyer's mounting medium (Borror and DeLong 1971). Female specimens (keys are available only for females) were examined under a compound microscope and identified using the keys of Chiappini *et al.* (1996) and Triapitsyn (1998).

We collected leafhopper nymphs and adults near Prosser from ornamental roses on 11 April and 10 May 2002 and from blackberry on 12 and 15 April 2002 to identify the species feeding on those plants. Specimens were identified using the descriptions in Elsner and Beers (1988).

RESULTS

We collected 132 plant samples comprised of 31 plant species from 52 different sites. A total of 733 female and 1068 male *Anagrus* was reared from 12 of the plant species (Table 1). *Anagrus erythroneura* was the most numerous grape leafhopper parasitoid collected (Table 1). It was reared from Himalayan blackberry, *Rubus armeniacus* Focke; Wood's rose, *Rosa woodsii* Lindley; sweetbrier rose, *R. eglanteria* L.; rugose rose, *R. rugosa*; willow, *Salix* spp. L.; and ornamental roses, *Rosa* spp. L. *Anagrus tretiakovae* was recovered from choke cherry, *Prunus virginiana* L.; ornamental roses, *Rosa* spp.; *R.. rugosa*; and Himalayan blackberry. One specimen, which was identified as *A. daanei* or a closely related species, was recovered from an ornamental rose (Table 1). *Anagrus atomus* L. was reared from Himalayan blackberry; evergreen blackberry, *R. laciniatus* Willdenow; *Rosa woodsii*, *R. eglanteria*; *R. rugosa*; willow, *Salix* spp.; ornamental roses, *Rosa* spp. and possibly from Antelope bitterbrush, *Purshia tridentata* (Pursh) de Candolle (Table 1). Some *Anagrus* specimens could not be identified due to their poor condition; usually they were missing antennae. Tentative identifications were given to *Anagrus columbi* Perkins, *A. daanei,* and some *A. nigriventris* Girault because the specimens did not exactly fit the descriptions in the keys. Voucher specimens are deposited at the Washington State University Irrigated Agriculture Research and Extension Center, Prosser, Washington.

The plants harbored from zero to six *Anagrus* spp. each (Table 1). *Rubus armeniacus* had the most *Anagrus spp.* with six. *Rosa* spp. had five species; *Salix* spp. and *R. rugosa* had three; *P. virginia, R. eglanteria* and *R. woodsii* had two each; and *Chrysothamnus nauseosus* (Pallas) Britton, *Prunus avium* L., *Purshia tridentata*, *Rubus lacinatus,* and *Salix babylonica* L. had one each (Table 1). *Chrysothamnus nauseosus* produced only one female with missing antennae and only one male emerged from *P. avium*.

All adult and nymph leafhoppers collected from roses or blackberries were rose leafhoppers, *Edwardsiana rosae* (L.).

Table 1.

Anagrus spp. reared from plants collected in south central Washington and north central Oregon during the winters of 2000 to 2007.

Plant scientific name	Plant common name	No. of years collected	No. of sites[1]	No. of samples	No. of branches	No. of *Anagrus* females	No. of *Anagrus* males	*Anagrus atomus*	*A. erythroneurae*	*A. tretiakovae*	Other *Anagrus*
Acer saccharum L.	Silver (sugar) maple	2	2	3	70	0	0				
Alnus rhombifolia Nuttall	White alder	1	1	1	20	0	0				
Artemesia tridentata Nuttall	Big sagebrush	3	3	3	41	0	0				
Celtis reticulata Torrey	Hackberry	1	1	1	12	0	0				
Chrysothamnus nauseosus (Pallas) Britton	Common rabbit brush	2	2	2	35	1	0				
Cornus sericea L., ssp. sericea	Red-osier dog-wood	3	3	4	86	0	0				
Cornus sp. L	Ornamental dog-wood	1	1	1	8	0	0				
Crataegus douglasii Lindley	Black hawthorn	2	2	2	42	0	0				
Lonicera involucrata (Richard) Banks	Bearberry honey-suckle	1	1	1	24	0	0				
Populus trichocarpa Michaux	Black cotton-wood	1	2	2	43	0	0				
Prunus avium L.	Sweet cherry	2	5	5	100	0	1				
Prunus cerasifera Ehrhart	Flowering plum	2	4	4	48	0	0				
Prunus domestica L	Prunes, Italian	1	1	1	12	0	0				
Prunus emarginata (Douglas ex. Hook.) Eaton	Bittercherry	1	1	3	68	0	0				
Prunus sp. L.	Flowering cherry	1	1	1	20	0	0				
Prunus virginiana L.	Choke cherry	5	10	13	296	4	3			3	1 *A. avalae*
Purshia tridentata (Pursh) de Candolle	Antelope bitter-brush	3	4	5	101	2	1	2?			

Table 1 (continued)

Plant scientific name	Plant common name	No. of years collected	No. of sites	No. of samples	No. of branches	No. of *Anagrus* females	No. of *Anagrus* males	*Anagrus atomus*	*A. erythroneurae*	*A. tretiakovae*	Other *Anagrus*
Ribes aureum Pursh	Golden currant	1	1	1	20	0	0				
Robinia pseudoacacia L.	Black locust	1	1	2	40	0	0				
Rosa eglanteria L.	Sweetbrier	4	5	5	106	28	12	5	20		
Rosa gymnocarpa Nuttall	Dwarf rose	1	1	1	22	0	0				
Rosa nutkana K. Presl	Nookta rose	1	1	1	20	0	0				
Rosa rugosa Thunberg	Rugose rose	2	3	3	50	5	7	1	3	1	
Rosa spp. L.	Ornamental rose	3	9	21	415	419	802	126	242	9	1 *A.* nr. sp. *daanei, 1 A. avalae*
Rosa woodsii Lindley	Wood's rose	8	10	10	215	26	31	5	20		
Rubus armeniacus Focke (R. discolor, R. procerus)	Himalayan blackberry	5	17	17	234	242	208	80	155	1	2 *A.* nr. sp. *columbi, 2 A. avalae, 1 A. nigriventris*
Rubus laciniatus Willdenow	Evergreen blackberry	1	1	1	11	1	0	1			
Rubus parviflorus Nuttall	Thimbleberry	1	1	1	10	0	0				
Salix babylonica L.	Weeping willow	1	1	1	35	1	0				1 *A.* nr. sp. *avalae*
Salix spp. L.	Willow	5	9	12	329	4	3	1	1		2 *A.* nr. sp. *nigriventris*
Vitis vinifera L.	Grape (leaf litter)	1	2	2	7 liters	0	0				
Vitis vinifera	Grape (canes)	1	2	2	56	0	0				
Total	31 species	-	108[1]	132	2589	733	1068	219, 2?	441	14	

[1] A total of 52 different sites were sampled. Some sites were sampled more than once.

DISCUSSION

Except for *Salix* spp. (Salicaceae) and *C. nauseosus* (Compositae) all *Anagrus* spp. were reared from members of the Rosaceae. Of the *Anagrus* overwintering plants that we found, *R. woodsii, Chrysothamnus nauseosus*, *Prunus virginiana*, *Purshia tridentata*, and *Salix* spp. are native plants; the others were introduced (Hitchcock and Cronquist 1973).

Anagrus erythroneurae was the most abundant (based on identified females) (Table 1). It was reared from several species of roses and from blackberry. The *Rosa* spp. appear to be new plant host records (Triapitsyn 1998, Williams and Martinson 2000). Although *A. erythroneurae* is the most common egg parasitoid of *E. elegantula* in northern California (Triapitsyn 1998), *A. tretiakovae* was about 10 times more abundant on *E. elegantula* in Washington (Prischmann *et al.* 2007). Biotypes of *A. erythroneurae* vary in their host preferences and rates of parasitism (Triapitsyn 1998). Thus, the introduction of more effective biotypes may be possible.

Although *A. tretiakovae* was the most abundant *E. elegantula* egg parasitoid collected from grape in Washington (Prischmann *et al.* 2007), it was found in relatively low numbers on non-grape plants (Table 1). The hosts were choke cherry, at least two species of rose, and blackberry (Table 1), all of which appear to be new host records (Triapitsyn 1998, Williams and Martinson 2000). The recovery of *A. tretiakovae* from *P. virginiana* suggests that other *Prunus* spp. such as French prunes (Kido *et al.* 1984) also may also be potential overwintering refuges.

Anagrus daanei has been found in other states on Virginia creeper, *Parthenocissus quinquefolia* (L.) Planchon; almond, *Prunus dulcis* (Miller) D. A. Webb; blackberry; apple (unconfirmed); *Acer saccharum* Marshall; *Robinia pseudoacacia* L.; *Rosa multiflora* Thunberg; and *Zanthoxylum americanum* Miller (Triapitsyn 1998, Williams and Martinson 2000). Because *A. daanei* has been recovered from blackberry and a species of rose, it may overwinter on these plants in Washington, although presumably in low numbers.

Anagrus atomus was found in relatively high numbers on several species of plants. *Salix* and *Purshia* are genera not previously reported as host plants (Triapitsyn 1998, Williams and Martinson 2000). Although *A. atomus* is not known from grapes in North America, it has been reported as a parasitoid of grape leafhoppers in Europe and Iran (Böll and Herrmann 2004, Hesami *et al.* 2004). Triapitsyn (1998) believes that European, grape-inhabiting *A. atomus* is a candidate for importation into the United States to control *Erythroneura* spp.

The main grape growing area of Washington is in the arid Columbia Plateau ecoprovince that historically was composed of shrub-steppe habitat, but much of the land has been converted to agriculture (NWHI 2007). Average annual precipitation at the Washington State University Irrigated Agriculture Research and Extension Center near Prosser was 19.2 cm from 1924 to 1976 (Kleingartner 1977) and 19.1 cm from 1986 to 2007 (PAWS 2007) with only about 5% of the precipitation falling in July and August combined. Therefore, almost all crops grown in this region need to be irrigated. Blackberry bushes grow in places where they can access water – often where the water table is high due to irrigation. Wild roses grow almost exclusively in riparian habitats, principally near the Yakima River. Attempts to increase leafhopper parasitism in California by planting blackberries near vineyards were not very successful, probably because the habitats were not favorable for the blackberries or their leafhoppers (Wilson *et al.* 1989). In south central Washington, refuge plants probably would need to be irrigated. Even drought resistant plants such as *Rosa rugosa* may need irrigation to be suitable hosts for leafhoppers. Because pesticides can cause mortality to leafhoppers and *Anagrus* spp. (de Courcy Williams and Gill 1996, Martinson *et al.* 2001), refuge plants should not be planted within vineyards or where they would be exposed to spray drift.

Blackberry and roses were good overwintering plants for the grape leafhopper parasitoids *A. erythroneurae* and *A. tretiakovae*. Other host plants, perhaps better ones, almost certainly exist. Because *A. daanei* was the most common parasitoid reared from *E. ziczac* eggs (Prischmann *et al.* 2007), finding an acceptable overwintering plant is critical for successful biological control of this leafhopper in south central Washington.

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